Electronic Version
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Claims

[c1] 1.A display with on-substrate muxing comprising:
a display substrate;
a display array of Micro-Electro-Mechanical Switches (MEMS) display elements for altering visible light, the MEMS display elements controlled by row and column signals, wherein each MEMS display element is controlled by a row electrode connected to a row signal and by a column electrode connected to a column signal;
a column mux having MEMS contact-switch elements, the MEMS contact-switch elements having a pair of contact electrodes that is electrically connected together when the MEMS contact-switch element is closed, but the pair of contact electrodes is electrically isolated when the MEMS contact-switch element is open;
wherein the column mux and the display array are formed on the display substrate, wherein the column signals to the display array are generated by the column mux;
wherein the column signals are not driven by an off-substrate column driver but are driven by the column mux; and
wherein an off-substrate interface to the column mux

has fewer signals than a number of the column signals to the display array,
whereby off-substrate interface signals for display columns are reduced using the column mux that is on the display substrate.

[c2] 2.The display with on-substrate muxing of claim 1 wherein the off-substrate interface to the column mux includes a display data word of data to be displayed, the display data word having N bits of data;
wherein the column mux drives a plurality of C column signals to the display array;
wherein C is at least 8 times larger than N,
wherein the column mux is at least a 1:8 mux wherein each bit of the display data word is multiplexed among at least 8 of the column signals to the display array.

[c3] 3.The display with on-substrate muxing of claim 2 wherein the off-substrate interface to the column mux further includes select signals to control selection of the MEMS contact-switch elements in the column mux to receive and store the display data word.

[c4] 4.The display with on-substrate muxing of claim 3 wherein the column mux comprises:
a plurality of one-bit MEMS storage muxes that each have a first MEMS contact-switch element responsive to

a first select signal applied to a control electrode and a second MEMS contact-switch element responsive to a complementary first select signal applied to a control electrode;

wherein an applied bit of the display data word is applied to control electrodes of both the first and second MEMS contact-switch element;

wherein a first fixed voltage is applied to a contact electrode of the first MEMS contact-switch element and is driven to a column signal when the applied bit is in a first state and the first select signal is activated;

wherein a second fixed voltage is applied to a contact electrode of the second MEMS contact-switch element and is driven to the column signal when the applied bit is in a second state and the complementary first select signal is activated;

wherein the column signal is driven with the first fixed voltage to close a MEMS display element in the display array after the applied bit is in the first state when the first select signal is activated;

wherein the column signal is driven with the second fixed voltage to open a MEMS display element in the display array after the applied bit is in the second state when the complementary first select signal is activated.

[c5] 5.The display with on-substrate muxing of claim 4

wherein the control electrodes control a state of the MEMS contact-switch element;
wherein when an absolute voltage difference between control electrodes exceeds a first threshold the MEMS contact-switch element is in a set state and the contact electrodes are electrically connected;
wherein when an absolute voltage difference between control electrodes is below a second threshold the MEMS contact-switch element is in a clear state and the contact electrodes are electrically isolated;
wherein when an absolute voltage difference between control electrodes is between the first and second thresholds the MEMS contact-switch element is in a hold state wherein the contact electrodes are electrically connected when a prior state was the set state, and wherein the contact electrodes are electrically isolated when the prior state was the clear state.

[c6] 6.The display with on-substrate muxing of claim 5 wherein the first and second MEMS contact-switch elements are in the hold state and hold the prior state when the first select signal and the complementary first select signal are driven to a holding voltage.

[c7] 7.The display with on-substrate muxing of claim 6 wherein the column mux comprises:
a plurality of C of the one-bit MEMS storage muxes;

wherein each bit of the display data word is successively input to a plurality of C/N of the one-bit MEMS storage muxes that generate C/N of the column signals.

[c8] 8.The display with on-substrate muxing of claim 7 wherein each one-bit MEMS storage mux further comprises redundant MEMS contact-switch element to allow for desired operation when a MEMS contact-switch element is faulty.

[c9] 9.The display with on-substrate muxing of claim 1 further comprising:

a row mux having MEMS contact-switch elements;

wherein the row mux, the column mux, and the display array are formed on the display substrate, wherein the row signals to the display array are generated by the row mux;

wherein the row signals are not driven by an off-substrate row driver but are driven by the row mux; and

wherein an off-substrate interface to the row mux has fewer signals than a number of the row signals to the display array,

whereby off-substrate interface signals for display rows are reduced using the row mux that is on the display substrate.

[c10] 10.A reduced-interconnect display comprising:

a display array of Micro-Electro-Mechanical Switch (MEMS) display elements controlled by row signals and column signals, each MEMS display element having a column electrode connected to a column signal and a row electrode connected to a row signal, wherein a gap between the row and column electrodes is a reduced gap when an absolute voltage difference between the row signal and the column signal exceeds a set threshold, and wherein the gap between the row and column electrodes is a enlarged gap when the absolute voltage difference between the row signal and the column signal is below a clear threshold, and wherein the gap between the row and column electrodes is unchanged change when the absolute voltage difference between the row signal and the column signal is between the set threshold and the clear threshold;

wherein visible light from the MEMS display element is altered when the gap changes between the reduced gap and the enlarged gap;

a mux array of Micro-Electro-Mechanical Switch (MEMS) switch elements each having a first control electrode, a second control electrode, a first contact electrode, and a second contact electrode, wherein (1) when an absolute voltage difference between the first control electrode and the second control electrode exceeds the set threshold the first contact electrode and second contact electrode

are electrically connected together; (2) when the absolute voltage difference between the first control electrode and the second control electrode is below the clear threshold the first contact electrode and second contact electrode are electrically isolated from each other; and (3) when the absolute voltage difference between the first control electrode and the second control electrode is between the set threshold and the clear threshold the first contact electrode and second contact electrode remain in a prior state;

wherein the mux array receives mux-select signals and display-data input signals that successively receive display data words and generates the column signals to the display array, and

a display substrate for supporting the display array of the MEMS display elements and the mux array of the MEMS switch elements, the display substrate being an integral part of the MEMS display elements and the MEMS switch elements;

wherein the column signals are directly driven by the mux array to the display array, reducing a number of signals for an off-substrate column interface.

[c11] 11.The reduced-interconnect display of claim 10 wherein the off-substrate column interface comprises the display-data input signals that receive a display data word

of N bits and a plurality of the mux-select signals to control the mux array;
wherein the display array has C column signals, wherein C and N are positive whole numbers and C is greater than N and C is a whole-number multiple of N;
wherein the mux array comprises a plurality of bit-muxes, each bit-mux receiving one of the N bits of the display data word and driving C/N column signals to the display array;
wherein each bit-mux receives all signals in the plurality of mux-select signals.

[c12] 12.The reduced-interconnect display of claim 11 wherein each bit-mux comprises:
a plurality of C/N one-bit MEMS storage mux cells, each one-bit MEMS storage mux cell receiving one of the N bits of the display data word as a data input, and driving one column signal to the display array in response to a mux-select signal in the plurality of mux-select signals.

[c13] 13.The reduced-interconnect display of claim 12 wherein each one-bit MEMS storage mux cell comprises:
a first MEMS switch element having a first control electrode receiving a mux-select signal, a second control electrode receiving a data input, a first contact electrode connected to a first fixed voltage, and a second contact electrode connected to drive the column signal; and

a second MEMS switch element having a first control electrode receiving a complementary mux-select signal, a second control electrode receiving the data input, a first contact electrode connected to a second fixed voltage, and a second contact electrode connected to drive the column signal.

[c14] 14.The reduced-interconnect display of claim 13 wherein the one-bit MEMS storage mux cell is activated by driving the mux-select signal to a first select voltage and driving the complementary mux-select signal to a second select voltage;
wherein the one-bit MEMS storage mux cell is deactivated and holds a prior state by driving the mux-select signal and the complementary mux-select signal to a de-select voltage that is between the first select voltage and the second select voltage.

[c15] 15.The reduced-interconnect display of claim 13 wherein the column signal is driven with the first fixed voltage by the one-bit MEMS storage mux cell to switch a selected MEMS display element to the reduced gap when the data input is in a first state and the one-bit MEMS storage mux cell is activated;
wherein the column signal is driven with the second fixed voltage to switch the selected MEMS display element to the enlarged gap when the data input is in a

second state and the one-bit MEMS storage mux cell is activated;

wherein the selected MEMS display element is in a selected row that has a row-selection voltage applied to the row signal for the selected row.

[c16] 16.The reduced-interconnect display of claim 10 further comprising:

a second mux array of the MEMS switch elements, the second mux array receiving row mux-select signals and row display-data-input signals, the second mux array for generating the row signals to the display array,

wherein the second mux array is an integral part of the display substrate;

wherein the row signals are directly driven by the second mux array to the display array, reducing a number of signals for an off-substrate row interface.

[c17] 17.The reduced-interconnect display of claim 16 further comprising:

a column pre-driver device, receiving a graphics clock and a stream of display data for display by the display array, for generating a row clock, the mux-select signals, and successive display data words transferred to the display substrate by the display-data input signals;

a row pre-driver device that receives the row clock from the column pre-driver device, the row pre-driver device

generating the row mux-select signals and the row display-data-input signals to the second mux array;
wherein the column pre-driver device and the row pre-driver device are not on the display substrate.

[c18] 18.A Micro-Electro-Mechanical Switches (MEMS) display comprising:
substrate means for supporting MEMS elements and conductive traces;
display means for altering light to generate a visible image, the display means having rows and columns of MEMS display means for altering a visible pixel by moving electrodes in response to an absolute voltage difference across the electrodes;
multiplexer means, on the substrate means and coupled to the display means by column traces, for storing successively received display data words to drive all column traces to the display means;
wherein the multiplexer means further comprises a plurality of bit-mux means for receiving one bit of the display data word and for driving multiple column traces from successive display data received;
wherein the bit-mux means comprises a plurality of one-bit MEMS storage mux means for storing the one bit of the data word and driving one column trace; and
wherein each one-bit MEMS storage mux means com-

prises a plurality of MEMS switch means for electrically connecting a first contact electrode to a second contact electrode when an absolute voltage difference between a first electrode and a second electrode exceeds a set threshold, and for electrically isolating the first contact electrode from the second contact electrode when the absolute voltage difference between the first electrode and the second electrode is below a clear threshold, and for maintaining a prior connection or isolation state when the absolute voltage difference between the first electrode and the second electrode is above the clear threshold and below the set threshold,
whereby muxing of the display data word is performed on the substrate means by the MEMS switch means.

[c19] 19.The MEMS display of claim 18 wherein each one-bit MEMS storage mux means comprises two MEMS switch means including:
a first MEMS switch means for driving a set voltage onto the column trace to set a MEMS display means in a selected row when the one bit of the display data word received is in a first state;
a second MEMS switch means for driving a clear voltage onto the column trace to clear the MEMS display means in the selected row when the one bit of the display data word received is in a second state.

[c20] 20.The MEMS display of claim 18 further comprising: transparency-weighted shading means, on the substrate means, for displaying shades of color by absorbing different amounts of light reflected from different MEMS display means, the transparency-weighted shading means having differing transparencies formed on the substrate means over different MEMS display means.